The MicroBooNE Experiment: Refining Sensitivity to ν_e Events

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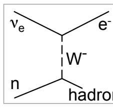
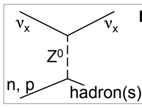
Abstract: The MicroBooNE experiment is a Liquid Argon Time Projection Chamber (LArTPC), which, like its predecessor MiniBooNE, will search for electron neutrinos in the Booster Neutrino Beam at Fermilab. MicroBooNE's main physics goals are to investigate the source of the unexpected excess of electron-like events at low energies observed by MiniBooNE, and to serve as a model for future large Liquid Argon detectors. MicroBooNE will begin taking data in 2013. This poster describes the main physics goals of MicroBooNE, and shows some preliminary predictions for electron-like background in MicroBooNE.

Neutrino Interactions

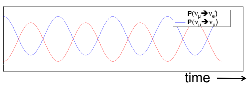
• Neutrinos interact with other particles through the weak force in one of the following types of interactions:



Charged Current (CC) can determine the flavor of the incident neutrino by the charged lepton that is produced



Neutral Current (NC) no charged lepton is produced, can gain no information about the neutrino flavor

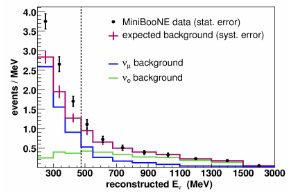


Source of ν_e events: Neutrino Oscillations

• Each weak flavor state (ν_e, ν_μ, ν_τ) is a linear combination of mass states
• Because the mass states evolve differently in time, a neutrino of one flavor does not remain the same flavor as it travels
• The probability that a neutrino of one flavor will oscillate into another flavor is given by

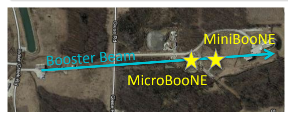
$$P(\nu_\mu \rightarrow \nu_e) = \sin^2(2\theta)\sin^2(\frac{1.267\Delta m^2 L}{E})$$

Motivations: MiniBooNE and the Low-Energy Excess



• MicroBooNE was largely motivated by the results of its predecessor experiment, MiniBooNE
• MiniBooNE results show that measurements of ν_e are in good agreement with predictions of background for neutrino energies above 475 MeV

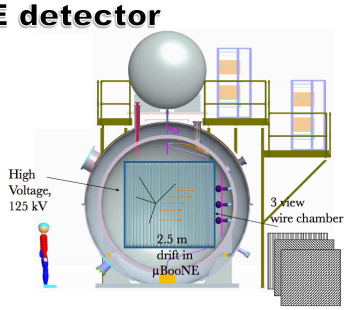
• But, MiniBooNE results show an unexpected excess of ν_e with energies between 200 - 475 MeV



• MicroBooNE will be located 470 meters from the neutrino production target (70 meters upstream of MiniBooNE) in the Booster Beam line

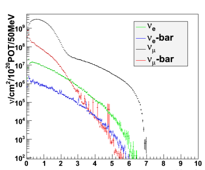
The MicroBooNE detector

• Detector volume is filled with 170 tons of liquid Argon, with 86 ton active volume
• Charged particles resulting from neutrino interactions ionize in Ar
• Electric field causes ionization electrons to drift towards three wire planes
• Signals on wire planes give information about charged particle positions and energy deposition (dE/dx)



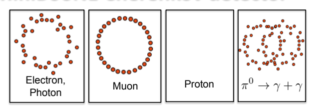
The Booster Neutrino Beam (BNB)

• The Booster Neutrino Beam is located at Fermilab
• MicroBooNE will collect data corresponding to a total of 6.6 x 10^{20} POT (protons on target)
• BNB flux (right) is dominated by ν_μ and $\bar{\nu}_\mu$
• MicroBooNE will search for ν_μ to ν_e & $\bar{\nu}_\mu$ to $\bar{\nu}_e$ oscillations by looking for ν_e & $\bar{\nu}_e$ appearance
• CC ν_e ($\bar{\nu}_e$) events can be identified by the e^- (e^+) produced in a charged current interaction



Advantages of the LArTPC for Particle ID

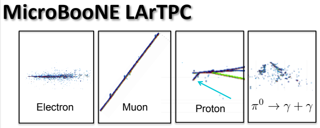
MiniBooNE Cherenkov detector



• Muons produce sharp rings in the MiniBooNE detector
• Both electrons and photons produce electromagnetic showers, which appear as fuzzy rings in the MiniBooNE detector

• MiniBooNE cannot distinguish photons from electrons
• Even a pair of photons can be mistaken for an electron if the rings overlap, or if one of the photons has very low energy and cannot be detected
• Therefore, events that produce photons, such as NC π^0 events, are a major source of background in MiniBooNE

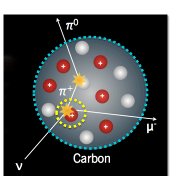
MicroBooNE LArTPC



• The LArTPC produces an even more detailed image of the event topology
• Even low energy protons, which are invisible in most detectors, can be identified

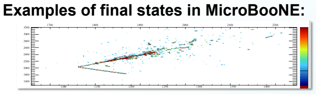
• MicroBooNE can distinguish between electrons and photons by looking at the energy deposition in the first few cm of the shower
• Electrons have a single MIP (Minimum Ionizing Particle)
• Photons have two MIPs since $\gamma \rightarrow e^+ + e^-$

Final States and electron-Like Events

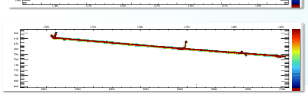


• **Initial state** particles: direct products of the ν interaction. In this case π^+ and μ^- (exiting yellow circle)
• **Final state** particles: those that exit the nucleus after the interaction. Here, π^0 and μ^- (exiting blue circle)
• The detector sees only the final state particles, not the initial state particles

Examples of final states in MicroBooNE:



1 e + 1 p

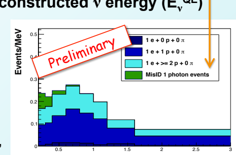


1 μ + 2 p

• Applying the MiniBooNE ν_e selection (1e + 0π in the final state) to MicroBooNE Monte Carlo allows us to study the final state nucleons that were not visible in MiniBooNE
• Looking at more inclusive event samples (1e + hadrons) will help boost statistics

Number of events vs. reconstructed ν energy (E_ν^{QE})

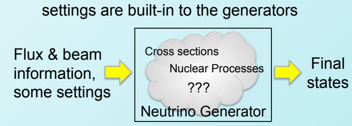
• Includes events with 1e + 0π in the final state, and 6% of events with 1γ + 0e + 0μ in the final state (mis-ID estimate)
• Assumes 6.6 x 10^{20} POT, 70t fiducial volume, and 80% efficiency



• More accurate predictions for electron-like events in MicroBooNE will weight each event according to how often its final state is mistaken for 1e + other

Neutrino Generators

• **Neutrino Monte Carlo generators are not all the same!**
- different generators use different cross section models, models of nuclear processes, etc.
- for some parameters, the user can specify the settings she would like to use. Other settings are built-in to the generators



• Comparing the predictions from different generators will help us understand the built-in model differences and quantify the systematic uncertainties associated with the predictions